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FLAME CUTTING TEXTURED STEEL ARMOR

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ABSTRACT

Lamellar and transverse edge cracks develop when textured steel armor is flame cut without preheat. The delayed nature of the transverse edge cracking suggests a contributing failure mechanism of hydrogen induced cracking. Recommended practices for flame cutting textured steel armor are presented.

INTRODUCTION

Undesirable metallurgical transformations and high tensile residual stresses[1] in the region of flame cut edges have necessitated the use of high preheat temperatures, often in excess of 550°F,[2] for the flame cutting of high strength steels. In addition, grinding is generally required for all thermal cut surfaces, not subjected to welding, if cut surfaces are on a part that is dynamically loaded.[3,4,5] The combination of high preheat temperatures and secondary grinding requirements translates to high cutting costs for high hardenability armor steels. The purpose of the work presented here is to establish oxy-fuel cutting guidelines for an ultrahigh hardenability armor steel, textured steel.[6] [illegible] crack [illegible] hydrogen induced cracking [illegible].

EXPERIMENTAL

Two inch thick textured steel plate was used in all flame cutting experiments. The chemical composition of the textured steel used is shown in Table 1. Typical mechanical properties of this material are shown in Table 2.

Cuts were made with a Linde CM 250 oxy-fuel shape cutter. A constant set of cutting parameters was used for all cutting trials, Table 3.

Table 1. CHEMICAL COMPOSITION OF TEXTURED STEEL

Weight Percent								
C	Mn	Ni	Cr	Mo	Si	P	S	Cu
0.40	0.58	5.43	0.11	0.46	1.24	0.006	0.005	0.97

Table 2. TYPICAL MECHANICAL PROPERTIES OF TEXTURED STEEL ARMOR

YS 0.2% Offset (ksi)	UTS (ksi)	Elon. (%)	R.A. (%)	Charpy Impact Energy, 22°C (ft-lb)
237	303	13.1	46	17.5

Table 3. FLAME CUTTING PARAMETERS

Fuel Gas:	Acetylene
Fuel Gas Pressure:	6.5 psi
Preheat Flame O_2 Pressure:	20 psi
Cutting O_2 Pressure:	[illegible] psi
Cutting Tip:	#8
Cutting Speed:	10 ipm

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2. RUGE, J. *Transformations and Reactions in the Heat Affected Zone During the Welding and Oxygen Cutting of Steel.* Welding in the World, v. 4, no. 3, 1966, p. 142-153.
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6. ZARKADES, A. *Improved High Strength Armor Steel Through Texturing.* U.S. Army Materials Technology Laboratory, AMMRC TR 79-52, September 1979.

An electric furnace was used for preheating plates for cutting. Preheat temperatures were kept below the tempering temperature of the base material, 350°F. Preheat time was two hours. Plates were pierced before preheating so that flame cutting could begin within two minutes from the time when the plates were withdrawn from the furnace.

Original plate size was 3' x 2'. Rectangular shapes were cut. Cuts originated from pierced holes, at a corner of the rectangular shape and 4" from plate edges, in order to maximize restraint conditions. All cuts were 4" from plate edges and at least 12" long.

All flame cut edges were inspected visually immediately after cutting and with liquid penetrant after cooling below 100°F. Inspection was carried out initially at hourly intervals, and progressed to 24-hour intervals. If discontinuities were found, mating cut surfaces were compared to determine if flaws existed prior to flame cutting.

RESULTS

The cutting parameters used produced high quality cuts with square kerf edges and minimum dross and serration depth. Results from a hardness traverse across a flame cut edge in a plate cut without preheat are shown in Figure 1.

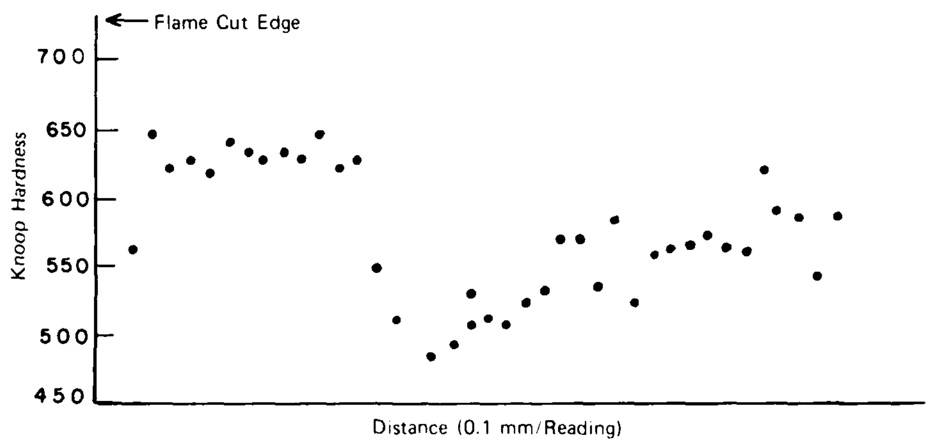

Figure 1. Hardness traverse across a flame cut edge in a plate cut without preheat.

Nondestructive testing results are summarized in Table 4. Lamellar cracks, with a stepped fracture appearance similar to that of a lamellar tear, were observed on all cut edges of plates cut without preheat. Cut edges of plates preheated to temperatures less than 325°F had transverse cracks, all occurring after a delay period of up to three weeks. These cracks, approximately 0.75" long, originated at the bottom edge of the cut and were only found on cut surfaces perpendicular to the rolling direction.

Table 4. NONDESTRUCTIVE INSPECTION RESULTS

Preheat Temperature	Inspection Results
Room Temperature	Lamellar and Transverse Edge Cracks - After 3 Days
200°F	Transverse Edge Cracks - After 3 Days
235°F	Transverse Edge Cracks - After 21 Days
275°F	Transverse Edge Cracks - After 3 Days
325°F	No Cracks
350°F	No Cracks

DISCUSSION

The delayed nature of the observed transverse edge cracking suggests that a hydrogen induced cracking mechanism may be operative. Preheat, therefore, is not only necessary for reducing hardness and residual stress values, but is also necessary for allowing additional time for atomic hydrogen to diffuse away from crack sensitive, martensitic heat affected zones.

Residual stresses from prior plate processing and the fact that thermal gradients increase with increasing distance from the preheating flames of the cutting nozzle[3] could explain why transverse cracks originated at the bottom side of the cut. Localized preheating with a cutting torch (from one side only) is, therefore, discouraged not only because it is difficult to control and overtempering of the base material is likely, but also because it may actually aggravate cracking tendencies.

The probability of transverse cracking is expected to increase with decreasing plate thickness due to the more severe thermal cycling encountered at the higher cutting speeds employed.[2] Also, the practice of flame cutting over a water table is not recommended due to the increased availability of diffusible hydrogen in the cut edge environment

CONCLUSIONS

Lamellar and transverse edge cracks develop when textured steel armor is flame cut without preheat.

The delayed nature of the observed transverse edge cracking suggests a contributing failure mechanism of hydrogen induced cracking.

The recommended preheat temperature for heavy sections of textured steel armor is approximately 325°F.

Preheating with a flame torch and cutting over a water table is not recommended, especially for thick sections.

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